5. Future State Assumptions

5.1 INTRODUCTION

A framework, or set of bounding assumptions, is required in order to limit speculation in performance assessments and compliance assessments about how changes that occur over time may effect the WIPP disposal system. The "Future State Assumptions" are designed to establish that framework by providing guidance on how to treat future uncertainties such as changes in demographics, changes in human physiology, changes in technology, advances in medical science. §194.25 states:

> (a) Unless otherwise specified in this part or in the disposal regulations, performance assessments and compliance assessments conducted pursuant the provisions of this part to demonstrate compliance with §191.13, §191.15 and part 191, subpart C shall assume that characteristics of the future remain what they are at the time the compliance application is prepared, provided that such characteristics are not related to hydrogeologic, geologic or climatic conditions.
>
> (b) In considering future states pursuant to this section, the Department shall document in any compliance application, to the extent practicable, effects of potential future hydrogeologic, geologic and climatic conditions on the disposal system over the regulatory time frame. Such documentation shall be part of the activities undertaken pursuant to § 194.14, Content of compliance certification application; § 194.32, Scope of performance assessments; and § 194.54, Scope of compliance assessments.
> (1) In considering the effects of hydrogeologic conditions on the disposal system, the Department shall document in any compliance application, to the extent practicable, the effects of potential changes to hydrogeologic conditions.
> (2) In considering the effects of geologic conditions on the disposal system, the Department shall document in any compliance application, to the extent practicable, the effects of potential changes to geologic conditions, including, but not limited to: dissolution; near surface geomorphic features and processes; and related subsidence in the geologic units of the disposal system.
> (3) In considering the effects of climatic conditions on the disposal system, the Department shall document in any compliance application, to extent practicable, the effects of potential changes to future climate cycles of increased precipitation (as compared to present conditions).

The final rule requires that performance assessments and compliance assessments shall include dynamic analyses of geologic, hydrogeologic and climatic processes and events that will evolve over the 10,000-year regulatory time frame. All other present day conditions will be assumed to exist in their present state for the entire 10,000-year regulatory time frame. These latter requirements apply to the future demographic and physiologic state of mankind, among all other assumptions necessitated by performance assessments and compliance assessments. Predicting the manner in which society will change would necessitate predicting the effect of historical, economic and political forces which typically bring about societal and demographic change. The speculative nature of such predictions precludes the development of an acceptable methodology for inclusion in the final rule that could make reliable predictions of the future state of society, science, languages or other characteristics of future mankind. For example, suppose that we know the current population density around the WIPP and we know that the population has grown at a certain rate over the last three decades (a very short time-frame when compared to the WIPP regulatory time-frame of 10,000 years). In addressing the future, one could extrapolate future population density based on the historical growth rate which might, over a 10,000-year regulatory period, result in unreasonable values, or one could assume that the population density remains constant (i.e., the status quo). The latter approach is to be used for future states. It is inappropriate to make long term predictions based on short term data. As in the population example above, certain activities are influenced by complex and interrelated forces (economics, government policy, etc.) and therefore cannot be predicted with reasonable accuracy.

Effects of climatic change are to be considered because they are reasonably predictable from the geologic record of the last several thousand years. However, there is no need for speculation on the possible secondary effects from climate change (e.g., increased precipitation which could allow irrigated agriculture near the site and change human economic activity and lifestyle) as these would be driven by the complex interrelated forces listed above. A similarly convincing basis exists as well for hydrologic and geologic conditions. This chapter will examine the body of scientific knowledge which may be used to extrapolate hydrologic, geologic and climate conditions into the 10,000 year regulatory time frame.

5.2 LAND USE AROUND THE WIPP SITE

Analyses of the WIPP's long-term performance will have to establish population and land use characteristics. The information provided below demonstrates how certain aspects of present-day demographics can be established and described for use in these analyses.

Population

The 1979 resident population within fifty miles of the WIPP Site is shown in Table 5-1.

These data were estimated for the 1980 WIPP Final Environmental Impact Statement (FEIS) (ALA79, DOE80). An examination of the US Census data indicated that the total Eddy County and Lea County population grew from 90,363 to 104,370 between 1970 and 1990 (DOC90). This is an average of about 0.7% per year. The 1990 Census data examined were not detailed enough to determine if there were changes in the population within 10 miles of the WIPP Site since 1979.

Table 5-1. 1979 Resident Population Within 50 Miles of the Site[a,b]

Sector[c]	0-5	5-10	10-20	20-30	30-40	40-50	Total
North	0	0	35	25	175	25	260
North-northeast	0	0	25	5	55	5,610	5,695
Northeast	0	0	0	25	75	8,660	8,760
East-northeast	0	0	15	70	205	33,200	33,490
East	0	0	5	15	3,240	155	3,415
East-Southeast	0	0	5	10	3,035	295	3,345
Southeast	0	0	5	15	25	30	75
South-Southeast	0	0	0	25	10	40	75
South	0	0	5	15	55	15	95*
South-southwest	6	0	5	30	90	15	145
Southwest	0	0	55	30	10	45	140
West-southwest	0	0	1,750	200	50	65	2,065
West	0	0	70	31,780	40	35	31,925
West-northwest	0	10	5	190	55	50	310
Northwest	0	0	30	20	65	12,055	12,170
North-northwest	0	0	15	5	220	10	280*
Radius Total	6	10	2,025	32,460	7,440*	60,305	102,245
Cumulative Total	6	16	2,040	34,500	41,940	102,245	

a Population estimated by Adcock and Associates (1977-1979).
b Figures for all areas beyond the 10 mile radius have been rounded to the nearest five.
c Distance from site (miles).
* The totals for this column and these rows are not in agreement with the numbers shown due to errors in the original data source.

Land Ownership and Use

Land in the vicinity of the WIPP is primarily owned by the Bureau of Land Management (BLM). Figure 5.1, included here from the WIPP FEIS (DOE80), illustrates land ownership for 1980. Since 1980, the following changes occurred in the Township 22 South Range 31 East (where the WIPP site is located): 1) the state-owned sections 16 and 32 were transferred to BLM in exchange for federal land elsewhere, and 2) the 4 by 4-mile area in the southwestern portion of the township was withdrawn for the WIPP site (see attached Figure 5.2 from DOE93).

At the WIPP, within its 16 mi^2 site, DOE presently controls 35 acres around the site's shafts and buildings (see Figure 5.2). Neither trespassing nor non-project uses are permitted in this area. Not shown in the figure is a 300-acre area around which DOE eventually plans to erect a five-strand barbed wire fence to prevent access to the area which overlies the repository footprint. DOE is presently considering extending the no-trespassing area to a total of 1,454 acres (see Figure 5.3), although grazing would be permitted on the newly added 1,154 acres.

Grazing and recreational uses – hunting, trapping, and off-road vehicle use – will be permitted on the remainder of the 16 mi^2 site. No surface or subsurface mining or exploration, nor water well drilling, will be permitted anywhere on the site except for two existing gas leases in section 31 at the southwest corner of the site. Land use immediately off the WIPP site allows for grazing, oil and gas exploration and production, extraction of sand, gravel, and caliche from surface pits, and recreational use. Figure 5.3 from the FEIS shows the location of some of these various activities. There is also extensive potash mining to the west, north, and northwest of the WIPP site. Figure 5.3 illustrates the locations of active potash mines relative to the WIPP site. Non-resident occupational employment within ten miles of the WIPP site is estimated to be 360 potash workers per shift (three mines) and twenty-four workers on cattle leases (ALA79, DOE90). Oil industry employment has not been estimated, but in 1990–1992 there were seventy-five oil and gas wells drilled within two miles of the WIPP site boundary (SIL94). A large agricultural area supported by irrigation is located along the Pecos River, which is 15–20 miles to the west and southwest of the WIPP (see Figure 5.3). Because of a scarcity of water in the fully allocated Pecos River Basin, the irrigated area is not likely to increase significantly.

Figure 5.1 Land Ownership Within 30 miles of the WIPP Site

Figure 5.2 WIPP Land Withdrawal Area and Surroundings

Figure 5.3 Land Use Within 30 Mile Radius of the WIPP Site

There are several highways near the WIPP site. US 62/180, connecting Carlsbad and Hobbs, is a four-lane divided highway located about nine miles north of the site which carries an average daily traffic flow of 1,850 vehicles (this and following averages were recorded in 1978). NM 128, about three miles south of the site, connects Carlsbad to Jal, New Mexico. This two-lane paved road conducts an average daily traffic flow of 220 vehicles. NM 31, about eight miles west of the site, connects NM 128 and US 62/180 and averages 510 vehicles per day. Numerous dirt roads in the area are maintained for ranching, pipeline maintenance, and oil and gas site access. In addition, there are now paved north and south access roads to the WIPP site from US 62/180 and NM 128, respectively. Most daily commuter traffic to the WIPP site uses the South Access Road. Present plans indicate all waste shipments arriving by truck will use the North Access Road. There is also a railroad spur connecting the WIPP site, but there are presently no plans for its use.

5.3 FUTURE STATES OF CLIMATE

Geologic, hydrologic, or climatic conditions are the only assumptions required by §194.25 to be predicted into the future. This section explicates part of the scientific record which can provide a basis for informed prediction of these three categories of events.

General State of Knowledge

Paleoclimatic data from southeastern New Mexico and the surrounding area indicate that the wettest and coolest Quaternary climate at the site can be represented by the last glacial maximum, when mean annual precipitation was approximately twice that of the present (SWI94). These data indicate that the hottest and driest climates have been similar to those of the present. The report also states that “the regularity of global glacial cycles during the late Pleistocene confirms that the climate of the last glacial maximum is suitable for use as a cooler and wetter bound for variability during the next 10,000 years.”

Mean annual precipitation at the WIPP has been estimated to be between 28 and 34 cm/yr (HUN85). Geologic data from southeastern New Mexico and the surrounding region show repeated alternations of wetter and drier climates throughout the Pleistocene, corresponding to global cycles of glaciation and deglaciation. Data from plant and animal remains and paleo-lake levels permit quantitative climate reconstructions for the region only for the last glacial cycle, and confirm the interpretation that conditions were coolest and wettest during glacial maximums (SWI93). Mean annual precipitation 22,000 to 18,000 years ago, when the last North American ice sheet reached its southern limit roughly 1500 km north of the WIPP, was approximately twice that of the present (SWI94).

The following text is quoted from SWI94, “Incorporating Long-Term climate Change in Performance Assessment for the Waste Isolation Pilot Plant.” It provides a general summary of the investigations which provide the basis for the 1992 WIPP PA assumptions regarding the potential for the range of future climatic extremes (SAN92).

> Glacial periodicities have been stable for the last 800,000 years (MIL41, HAY76, IMB84, IMB85). Barring anthropogenic changes in the Earth’s climate, relatively simple modeling of climatic responses to earth’s orbital changes suggest that the next glacial maximum will occur in approximately 60,000 years (IMB80). The extent to which unprecedented anthropogenic climate changes may alter this conclusion is uncertain, but presently available models of climatic response to an enhance greenhouse effect (MIT89, HOU90) do not predict changes of a larger magnitude than those of the Pleistocene. Furthermore, published models do not suggest significant increases in precipitation in southeastern New Mexico following global warming (WAS84, WIL87, SCH87, HOU90). Even allowing for anthropogenic change, climate variability at the WIPP can be bounded by Pleistocene extremes (SWI93).

The estimated mean annual precipitation at the WIPP during the late Pleistocene and Holocene is shown on Figure 5.4.

SWI93 draws the following three conclusions regarding climatic trends. First, maximum precipitation in southeastern New Mexico in the past coincided with the maximum advance of the North American ice sheet. (Minimum precipitation occurred after the ice sheet had retreated to its present limits.) Second, past maximum long-term average precipitation levels were roughly twice present levels. Minimum levels may have been 90% of present levels. Third, short-term fluctuations in precipitation have occurred during both the glacial maximum and the present, relatively dry, interglacial period, but fluctuations during the present interglacial period have not exceeded the upper limits of the glacial maximum.

SWI93 also states: “It would be unrealistic to attempt a direct extrapolation of precipitation {a figure is referenced} into the future. Too little is known about the relatively short-term behavior of global circulation patterns, and it is at present impossible to predict the probability of a recurrence of a wetter climate such as that of approximately 1000 years ago.

Figure 5.4 Estimated Mean Annual Precipitation Rate at the WIPP During the Late Pleistocene and Holocene (SWI93)

The long-term stability of the patterns of glaciation and deglaciation, however, do permit the conclusion that future climatic extremes are unlikely to exceed those of the late Pleistocene. Furthermore, the periodicity of glacial events suggests that a return to full glacial conditions is highly unlikely within the next 10,000 years."

Glaciation

Southeastern New Mexico is far from any region where extensive Pleistocene continental glaciation occurred. It is highly improbable, even in the event that global "icehouse" conditions developed, that the WIPP site would be affected by continental glaciers. In turn, the probability of glaciers and glacial erosion directly affecting the WIPP site is extremely small. *Alpine* glaciation, however, was quite extensive in northern New Mexico during the Pleistocene (CHR87). Evidence for alpine glaciers extends down to elevations of at least 8000 feet, possibly less. These glaciers, their deposits, and meltwaters affected and continue to influence the regional hydrology and Quaternary stratigraphy of this region. In the event of a major climatic change, alpine glaciation might be possible in the Guadalupe Mountains which have maximum elevations greater than 8000 feet (Guadalupe Peak is 8751 feet high).

5.4 GEOLOGIC FUTURE STATES

Sea-level fluctuations and hurricanes/seiches/tsunamis

The likelihood of sea-level fluctuations and hurricanes/seiches/tsunamis can be considered to be small due to the elevation (~3,300–3,500 feet) and landlocked position of the WIPP site. These conditions ensure that it will neither be inundated in the event of a eustatic sea-level rise (not even a rise of unprecedented scale) nor will it be affected by any catastrophic ocean current.

Regional uplift and subsidence

The Rio Grande Rift, an elongate, fault-bounded, extensional feature that extends roughly north-south across central New Mexico, began to form about 30 million years ago. One segment of the Rio Grande Rift, called the Tularosa Basin, is located within 150 km of the WIPP site. Extension continues within the rift today, as expressed by numerous active fault scarps that cut through Quaternary deposits (BLA76; CHA79; OLD89). There is some suggestion, based on the timing of development of structural features across the region, that extension may be slowly propagating eastward, toward the WIPP site. While long-term, rates of regional uplift/subsidence may not increase drastically over the next 10,000 years, detailed studies of Quaternary seismic activity and co-seismic fault slip should be done in the vicinity of the WIPP site in order to substantiate the claim that episodic, short-term uplift/subsidence will not compromise the integrity of the repository. This will largely entail detailed field mapping and analyses of Quaternary stratigraphy and structural features.

Landslides

The Pecos River, the largest river in the vicinity of the WIPP site, flows within 12-15 miles of the site. The difference in elevation between the Pecos River and the WIPP site is approximately 400 feet. It should be feasible to determine whether inundation of the WIPP site is possible in the event that a landslide dams or diverts the river at any of several different points along the river. A worst-case scenario might involve: 1) a landslide that dams the river where it is narrow, slightly downstream from, yet close to, the WIPP; 2) the landslide occurs during the annual peak discharge of the Pecos River; 3) the landslide and damming of the river occur at the same time as major flooding in southeastern New Mexico; and 4) the landslide occurs at a place along the river where the adjacent topography is such that flood waters are preferentially funneled toward the WIPP. Examination of aerial photographs and land-based studies might allow determination of the frequency of landslide events along the banks of the Pecos River and whether or not the (paleo)Pecos River ever flooded areas far beyond its "historical" flood plain. Furthermore, under pluvial conditions, the Pecos River may not maintain its current course in the future. Cores and/or trenches through Quaternary alluvium also might help with determining the frequency and magnitude of flooding events near the WIPP site.

Seismic activity (and faulting)

The main concerns regarding seismic activity and co-seismic slip or initiation of faults are: 1) whether the fault cuts through the repository and cumulative slip along the fault then brings radioactive waste into physical contact with circulating ground water; or 2) whether seismic events cause permeable faults or fracture zones to develop which lead to hydrologic communication between waste in the repository and circulating ground-water.

Given the tectonic setting of the WIPP site and the proposed depth of the repository, it is highly improbable that cumulative slip on a hypothetical fault that cuts through the repository could bring waste into contact with aquifers that sandwich the repository within 10,000 years. Thus, it seems reasonable to eliminate this from geologic scenarios, although as mentioned above under "Regional uplift and subsidence," detailed studies of the neotectonic activity around the WIPP site seem warranted.

New faults or fractures also could breach the repository and allow circulating ground waters to move through the repository and transport radionuclides to the surface or to shallow aquifers.

Volcanic and magmatic activity

Given the following, however, it seems reasonable that the inception of volcanic or magmatic activity is unlikely over the next 10,000 years and need not be considered in geologic scenarios: 1) the WIPP site is located presently in a relatively tectonically quiescent setting; 2) the WIPP site probably will remain tectonically quiescent over the long-term, based on present and projected vectors of motion for the North American plate and adjacent plates; and 3) volcanic/magmatic activity is typically associated with active, plate-margin settings (either extensional, compressional, or strike-slip settings), while mid-plate volcanism/magmatism is much less common and is related to deep-seated, mantle processes. The studies outlined previously under Regional uplift and subsidence would enhance confidence in the conclusion that volcanic and magmatic activity need not be considered as geologic scenarios.

Earthquakes produced by subsurface fluid injection/removal

Injection or removal of subsurface fluids during recovery of hydrocarbons is known to produce earthquakes. Earthquakes with magnitudes as high as 5.0 on the Richter scale, but generally between 1.0 to 3.0, are known from some areas (HOL68). Earthquakes of this type have been recorded in the Permian Basin (largely anecdotal evidence). Hazard assessment for the WIPP site should include the possibility of human-induced earthquakes as there are productive oil fields near the WIPP site that are currently under waterflood. Even small scale earthquakes could affect the integrity of seals.

5.5 HYDROLOGIC FUTURE STATES

The hydrologic properties of the geologic strata within the disposal system can be changed due to the occurrence of natural processes and events. As an example, dissolution may, in the future, affect the hydrologic properties of the Culebra dolomite layer of the Rustler Formation. The presence and degree of fracturing in the Culebra dolomite is thought to be directly related to the amount of dissolution of halite occurring below the Culebra (SNY85). As the magnitude of fracturing and development of secondary porosity increases, the Culebra transmissivity generally increases (CHA85). Based upon observations of outcrops, core, and detailed shaft mapping, the Culebra can be characterized as a fractured medium, at least locally, at the WIPP site (CHA84; HOL84). Aquifer tests also indicate responses characteristic of a fractured media (BEA87).

Dissolution within the Rustler Formation is observed both at the surface within Nash Draw, and in the subsurface at the WIPP site. Nash Draw, located immediately west of the WIPP site, is a depression resulting from both dissolution and erosion (BAC81). In Nash Draw, members of the Rustler are actively undergoing dissolution and locally contain caves, sinks, and tunnels typical of karst morphology in evaporitic terrain (HAU87).

BAC80 identified three types of dissolution occurring in the Delaware Basin: local dissolution, regional dissolution, and deep-seated dissolution. Local dissolution is the near-surface dissolution where surface or ground waters penetrate soluble strata though joints or fractures, causing local dissolution and possible collapse and fill, as well as dissolution features such as shallow caves above the regional water table. Regional dissolution occurs when chemically unsaturated water penetrates to permeable beds, where it migrates laterally, dissolving the soluble units which it contacts. On a regional scale, the consequence of such dissolution appears to be removal of highly soluble rock types, such as halite, combined with displacement and fracturing of adjacent rocks. Deep-seated dissolution occurs well below the water table, forming caverns within the rock.

At the WIPP site, regional dissolution is thought to have occurred within the Rustler Formation in the past (SNY85). However, there is some controversy as to whether this dissolution front is still active. BAC85 feels that most of the dissolution in the Rustler predates or occurred during a much more humid time in southeastern New Mexico over 500,000 years before present. BAC85 does suggest, however, that dissolution is still active in Nash Draw in areas very close to Livingston Ridge.

In the Rustler Formation at the WIPP site, most investigators feel that a westward increase in regional dissolution is reflected by a decrease in the number and thickness of halite beds and subsequent thinning of the Rustler Formation (HAU87). The stratigraphic level of the first occurrence of salt is in the upper Rustler along the eastern margin of the WIPP site, and progressively moves down-section through the Rustler as one moves west. As the bedded halites are dissolved, insoluble residues remain, forming beds of mudstones, siltstones, and chaotic breccia with a clay matrix (HAU87). Halite beds in the non-dolomitic members tend to be thin and grade westward into the residuum. Although most investigators concur with the premise that a dissolution front exists in the Rustler Formation at the WIPP site (COO71, POW78, MER83, CHA84, SNY85), there are some investigators who oppose this concept and believe that the westward decrease in halite within the Rustler represents depositional limits (LAM83, HOL84). HOL84 reported that, in their detailed mapping of the Rustler in the waste-handling shaft, no post-depositional dissolution features were identified.

Whether or not the dissolution front hypothesis is correct, there are general trends associated with the presence or lack of bedded halite within the Rustler Formation. As the presence of bedded halite within the Rustler increases, so does the thickness of the formation. Generally, as the amount of halite in the Rustler decreases, the transmissivity of the dolomitic members increases (HAU87), presumably from increased fracturing of the units as a result of halite removal and subsequent foundering and collapse of the more competent dolomite beds. In parts of Nash Draw, hydraulic potentials in the Magenta and Culebra are essentially the same (i.e. no vertical movement up or down). As one moves eastward onto the Livingston Ridge surface, the difference in hydraulic potentials between the two units increases. This could represent the increase in the effectiveness of the Tamarisk Member as a confining unit (or aquitard) with decreased halite removal (HAU87).

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